E. I. du Pont de Nemours and Company	Mohawk Industries, Inc.	PTT Poly Canada, L.P.

January 21, 2008

Office of Secretary
Federal Trade Commission
600 W. Pennsylvania Ave., NW
Washington, DC 20580

Petitioners' Response To Comments Submitted Regarding the September 7, 2006 Petition To Establish A New Generic Sub-Class for Fibers Made From PTT

Mohawk Industries, Inc. (Mohawk), E. I. du Pont de Nemours and Company (DuPont), and PTT Poly Canada, L.P. (PTT Canada) (collectively "Petitioners") submit the following comments and additional information ('Petitioners' Response) regarding (a) the 48 supportive comments submitted by carpet retailers and professionals, an independent testing laboratory, and a large Italian manufacturer of yarns and fabrics that support Petitioner's September 7, 2006 Petition (the "Petition") for the designation of a new generic subclass for fibers made from PTT, (b) the sole opposing comment submitted on November 9, 2007 by Invista S.a.r.l.[1], and (c) the proposed new generic names submitted with the Petition.

a) Petitioners' Comments Regarding Letters Submitted By Carpet Retailers and Professionals

Petitioners submit that the 48 comments submitted to the FTC in support of the Petition demonstrate that the scientific evidence submitted by Petitioners correlates well with observations by carpet professionals, an independent testing laboratory, and a fabric manufacturer regarding the performance of carpet and fabric produced from PTT fibers.

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[1] At page 7 of Invista's comments, Invista raises an issue unrelated to the issues raised in the Petition regarding Mohawk's labeling of carpets manufactured from PTT fibers. Since DuPont and PTT Canada are merely suppliers of polymer and do not manufacture or label carpet or carpet fibers, they do not take a position on this issue. Mohawk, however, submits that Invista's allegation that Mohawk "apparently chose to ignore the Act" and improperly labeled such product "for over a year" is inaccurate, needlessly inflammatory and wholly irrelevant to the Petition. In this regard, Mohawk submits that within a few months of it shipping the first samples of carpet made with PTT fibers in 2005 it was alerted to the requirement to include the generic fiber name on the label of such product. Mohawk further submits that it then promptly modified its labeling practices to include the "polyester" designation for such product and implemented a program to "sticker" sample product already in the marketplace. While Invista is not suggesting that Mohawk's current labeling is inadequate, its reference to this brief period in 2005 should be viewed as nothing more than a smokescreen designed to obscure the merit of the Petition.

There follow excerpts from a representative sampling of these 48 letters and e-mails submitted to the FTC:

Comments From Carpet Retailers

Southern Tile and Carpet

PTT fiber is a better product than what people traditionally think of as polyester since PET historically has not had a good wear characteristics. If called polyester, it is misleading to the consumer and the dealer as to how good the product really is. The product performs so much than PET that it should be allowed a new name.

Burton Floor Covering

According to Mohawk, Burton Floor Covering, Inc. is one of their largest users of Sorona in this market. I believe that with the styling, feel, look, and durability, as well as being virtually claim-free, the Sorona fiber should be a stand alone fiber. It should not be related or categorized as a polyester.

C&J Carpet Center

C & J Carpet Center has used both P.E.T. polyester and P.T.T. polyester. We have found that the P.T.T. products have had a superior history. They are much more resilience and have superior stain resistance. We have also found them to have a much softer feel.

We find that because the product has to be labeled as polyester, that many of our customers confuse these products made with P.T.T. with the products made with P.E.T. products. Because P.E.T. products don't perform at the same level as the P.T.T., some of our consumers that have had the P.E.T. in the past are more likely not to purchase these products based on past results. The average consumer does not understand that these products are very different in their performances. Therefore we feel that a separation is very much needed.

Carol's Carpet, Inc.

Carol's Carpet, Inc asserts the following: 1) PTT fiber is a better product than what people traditionally think of as polyester since PET historically has not had good wear characteristics. If we have to call it polyester, it is misleading the consumer and the dealer as to how good the product really is. 2) Our experience shows that the product performs so much better than a PET that it should be allowed a new name. 3) Prior experience with PET has jaded dealers and caused them to not want to sell anything called polyester. Forcing a fiber, with much better performance than a PET, to use the same name, will limit the consumer's ability to purchase the product.

Coastal Carpet & Tile

Having been in the floorcovering business for over 20 years, we have seen many things come and go in our industry. Now we have something, which is truly new, exciting and will be a great consumer product. Mohawk has created the PTT fiber system, which unlike its predecessors is performing well above standard. Unfortunately its composition is similar to the traditional polyester fiber which dealers have had many bad experiences with.

The mere mention of the word "Polyester" in our industry brings about nothing but negative images in the dealers and consumers minds. So, to group this new breakthrough fiber in the polyester category is unfair to all parties from the makers to the end user.

Colonial Floors

I have been in the floor covering business for over 28 years and have seen many new fiber introductions and, generally, the last better than the previous. However, this new fiber introduction which has a molecular structure that of polyester, yet is substantially more durable and stain resistant, is a gigantic leap forward in technology. Polyester has a history, in my business, of not having good wear characteristics. The new "Smartstrand" fiber wears extremely well, so well that it is on a par with nylon carpet. I have done my own testing on this product to assure myself and my customers that it will perform as claimed, and it has! So, in my opinion, it should not be put on an equal footing with polyester fibers. To do so would be to mislead our customers.

Commercial Surfaces, Inc.

It would be a terrible disservice to our industry to label this as a polyester fiber. The characteristics are not consistent with the poor long term performance we witnessed in carpet made from polyester fiber, such as pilling, crushing, and difficulty to dye. This is a fiber that must have its own identity to parallel with its outstanding performance.

Tom Davis Flooring

PET is generally associated with polyester, which people view as lower end product because of its negative track record. Forcing a fiber that is in a category far above PET to use the same name is misleading the buyer as to how good the product really is.

A&R Flooring, Inc.

I would like for the Smartstrand Carpet to not say polyester because it tends to lead customers away from the product. We all know that it is a wonderful product and would like to sell more of it. I feel as if the back of the carpet saying "polyester" is a misrepresentation.

Flooring Gallery

I have been: selling polyester since 1978 and the new PTT for approximately two years. This new fiber performs in such a superior manner we are doing an injustice to our customers by calling it polyester. The product we have installed in all or our showrooms, is out performing nylons that were installed at exactly the same time.

Our 1978 experiences with polyester caused us to be unable to sell it for many, many years. We now have a new performance tested product that out wears PET so well that it should be allowed a new name. We no longer want to taint the consumer consideration for this product by calling it a PET. Please strongly consider this new sub class and allow this fantastic new fiber to be sold for what it truly is.

Greer Flooring Center

The product is far different from traditional "polyester" products. People can feel the obvious difference in the product, as Sorona products are much softer than most polyesters of similar construction. When we tell the customer about the built in permanent stain resistance and the lack of any fluorocarbons to protect the fiber they wonder how this can be a polyester product. For that matter, so do our salespeople as they have built up many prejudices about polyester over the years. Forcing a fiber with much better performance than PET to use the same name, will limit the consumer's ability to purchase the product.

Kelly's Carpet

As a retailer it is important to have PTT in its own class because classification as polyester is misleading to our customers. While having the general chemical composition of polyester, PTT wears much better and should not be in the same class. I have never had a wear complaint on PTT, however I can't say the same about polyester. The performance of P'TT is not comparable to polyester and having PTT in the same class as polyester is not only rnisleading to consumers, but can make it difficult to sell because consumers think it will wear like polyester.

The Floor Store

I have been selling carpet for many years now, & carpet made from PTT definitely is more durable, more stain resistant & softer than any polyester fiber I have ever seen. The response from customers has been nothing short of amazing!

Mill Creek Carpet & Tile

Mill Creek Carpet and Tile, with its 11 store locations, has been selling this fiber for the last two and one-half years and has not filed a single consumer complaint over that time period. Contrary to original polyester (PET) fiber products, this amazing fiber has separated itself from all other classifications in my opinion.

Our samples carry the fiber description as "polyester" but the former reputation of that classification should not apply to this new "wonder fiber". The stain resistance, texture retention, and overall beauty of the finished product demonstrate a dramatically upgraded finish compared to those products made with PET.

J&J Carpets, LLC

In deciding whether to give PTT a sub class of polyester fiber, I think it SHOULD be given a separate category because of it's better wear characteristics and it performs better than the PET polyester products that are now on the market. Sales people and consumers alike will be misled if this new product is lumped in with the present polyester fibers currently available and will not know how good this PTT fiber product really is unless it is classified differently.

McCool's Flooring

As an owner/manager of McCool's Flooring, a four store family flooring business, and McCool's Floor Care, a Mohawk Floor Care Essentials carpet cleaning business, I would like to express my opinion of giving PTT fiber a new classification other than polyester. I personally have had the opportunity to clean PTT after it has been installed for at least one year. I am qualified and able to tell by the look of the carpet after normal wear what kind of fiber it is. I am always able to easily distinguish PET yarn by its notable matting in higher traffic areas. This situation is not noticed when carpet is nylon or PTT.

Capitol Carpet and Tile

Putting PTT fiber in the same subclass as PET is misleading. The performance is far superior to PET. In addition as a retailer we have never

had a claim ever, which I cannot say about any other fiber. In addition, because PET does and has not performed as well as some other fibers, it has a bad connotation for retail salespeople as well as consumers. Considering that PTT performs so much better then PET it is not only unfair not to give it a new name it is definitely misleading to the consumer. Putting PTT in a separate subclass will rightfully distinguish it from the inferior PET products.

Prattville Carpet, Inc.

We feel PTT fiber, while having the general chemical composition of polyester, is a better product than what people traditionally think of as polyester. PET historically has not had good wear characteristics and many customers will not even consider this product. If we have to call it polyester, we believe it will mislead the consumer as to how good the product really is. The product performs so much better than PET that it should be allowed a new name. Furthermore, forcing a fiber, with much better performance than PET, to use the same name, will limit the consumer's ability to purchase the product.

Premier Carpets

We at Premiere Carpets have used both P.E.T. polyester and P.T.T. polyester and have found in carpet installations that the P.T.T. products have had a superior history as far as resilience and stain resistance as well as a much softer hand in feel. We have found that since the product has to be labeled as polyester that' " many consumers compare these products made with P.T.T. with the products made with P.E.T. Since P.E.T. products don't perform at the same level as the P.T.T. goods some consumers that have had P.E.T. in the past are more likely not to purchase these products based on past results. This happens even though the products perform differently. We feel that a separation is very much needed.

Professional Carpet Systems

We have been in business for 20 years selling and installing carpet and have seen many changes in the industry. I have had the chance to test PTT fibers and have been impressed with the way that they perform. We have sold & installed Smartstrand carpet over the past year or so, with very positive results from our customers.

The problem that we do encounter is the stigma that surrounds the polyester label that has been placed on this product. Customers have a pre-conceived notion about polyester fibers and at times tend to steer clear of this product just because of that label. I feel that this makes a more difficult sales process for us, and is also unfair to the product.

Based on the tests that we have done, and the response that we have received from the customers that have purchased a PTT fiber product, we feel that it should carry a label different from PET, since it is obviously a different product and performs and wears much better than PET.

Accoustical Floors Inc.

Based on prior experience with PET fiber we have had a tough time getting customers to separate it from PTT fiber. The PTT fiber is much more resilient than your standard PET products are. However, due to the association with polyester we have a hard time separating the two in the customers mind. Are experience with the PTT fiber has been that it is far superior than that of the PET polyester fiber. As a retail flooring establishment we would like to see PTT product class.

Airbase Carpet Market

Historically, PET polyester has had a bad reputation compared to other fiber systems made from nylon and olefin. At one point in its history, many carpets made from PET polyester failed so miserably that retailers had to replace many jobs which quickly gave PET polyester a bad name. Today, through technological advancements in heat setting, the twist has improved and the carpets do perform. However, the reputation of PET polyester still remains tainted by its past. I am very supportive of the new fiber technology of PTT as it will allow us, the retailer, to sell with more confidence. While the new PTT fiber does have the same general chemical composition of polyester, it is unfair to the consumer to label it as such because she will believe that the fiber will perform poorly like PET polyester of the past and will be inferior to its counter part fiber systems in nylon today. At the same time, the exact opposite is true; the fiber performs much better then PET and is comparable to premium nylon products. For this fiber to be successful and the consumer to have a clearer understanding of its benefits, it is imperative that it not be labeled as polyester. This product performs so much better than PET that it should be allowed a new name that extols its benefits and will not confuse the consumer by PET polyesters soiled and matted past.

Comments From Independent Carpet Testing Laboratory

Independent Textile Testing Service, Inc.

Over the past 10 years we have been involved in extensive testing of the PTT fiber pertaining to carpet usage. Testing has included everything from pedestrian traffic, soiling, staining, static, colorfastness to atmospheric contaminants, flammability and many others. Based on our experience with the PTT fiber, it would seem that the test results consistently show a marked difference when compared to PET in regards to performance. Not knowing the chemistry patents and processes for this PTT yarn, we are at the understanding that the polymeric structure is very similar to PET. However,

the significant overall performance of the fiber to foot traffic and in use areas is remarkably better. It is of our opinion that the differences shown do indeed indicate that a need for a separate classification is a good idea. It would be very difficult to continue to try and let the marketplace separate these on its own. PTT indeed performs much better in general than PET in traffic ratings and it would benefit the consumer to know that there were distinct differences, thereby eliminating PET from being confused with PTT. We think a separate class of fiber generic name would be in good order and an overall benefit to end users.

Comments From Italian Manufacturer Of Yarns and Fabrics

Filature Miroglio S.p.A.

We have proved that PTT yarns give to the final product (textile fabrics and garments) different and specific properties compared to standard polyester like better: softness, drapability, abrasion resistance (especially important for upholstery and rugs application), resilience, recovery. PTT has as well easy care capability and is easy dyable allowing energy consumption diminution. PTT has a natural touch that allows it to be blended with natural fibers as well as with man-made and elastomeric filaments. In the interest of the consumer, we support the idea, based on the previous argumentation, PTT should be differentiated from standard polyester.

Petitioners submit that there are consistent themes running through these supportive comments which can be summarized as follows:

Conventional polyester (PET) has disappointed carpet consumers with its performance and has a bad reputation with both carpet retailers and consumers.

The performance of carpet made from PTT fibers is far superior to polyester and approximates the performance of nylon carpet with respect to resilience and resistance to wear. In addition, carpet made from PTT fibers is perceived to be softer than carpet made from PET fibers

PTT fibers when used in the manufacture of fabrics provide different and specific properties compared to standard polyester namely superior softness, drapability, abrasion resistance, resilience, and recovery.

Requiring carpet and apparel made from PTT fibers to be labeled as polyester is misleading to the consumer because the properties of PTT are far superior to the properties of PET in carpet and apparel applications.

Requiring carpet made form PTT to be labeled as polyester makes it difficult to sell such carpet because consumers and others in the carpet industry associate the generic "polyester" with poor carpet performance. A fiber regulation that would permit consumers to identify carpet and apparel products made from PTT fibers would provide consumers with additional choice.

While the carpet retailers and professionals referred to a variety of attributes of carpets made from PTT fibers, there is broad agreement that with respect to the three carpet performance attributes identified at pages 3 and 4 of the Petition, PTT fibers offer significant performance advantages over fibers made from PET. These attributes were:

> The carpet will stand up to years of foot traffic without matting down
>
> The pile of the carpet stays tight and will stand up like new after normal vacuuming
>
> The carpet is soft and comfortable to sit on or lie on

The Italian fabric manufacturer which submitted comments regarding the properties of fabrics made from PTT fibers likewise commented on both the softness and resilience of such fabrics.

Petitioners submit that these themes and comments concerning carpet and fabric attributes confirm that the scientific evidence submitted by Petitioners meets the regulatory requirement for designation of a new sub-generic class for fibers made from PTT. Moreover, many of the companies submitting these supportive comments indicate that consumers would benefit from a new generic designation that would permit consumers to differentiate between products made from PTT from products made from PET.

Petitioners refer to one additional piece of evidence that supports the Petition, albeit from a surprising source. Figure 1 below is a table published by Invista S.a.r.l. as a link under its Stainmaster web site.

Figure 1

	STAINMASTER® NYLON TYPE 6,6 FIBER	NYLON TYPE 6 FIBER	POLYESTER PET (2GT)	POLYESTER PTT (3GT)	OLEFIN POLYPROPYLENE
ASSORTMENT OF COLORS & STYLES	EXCELLENT	EXCELLENT	GOOD TO FAIR	GOOD TO FAIR	FAIR
APPEARANCE RETENTION	EXCELLENT	EXCELLENT TO GOOD	POOR	EXCELLENT TO GOOD	POOR
RESISTANCE TO FOOT TRAFFIC & FURNITURE WEIGHT	EXCELLENT	EXCELLENT TO GOOD	POOR	EXCELLENT TO GOOD	POOR
OILY SOIL RESISTANCE	EXCELLENT	EXCELLENT TO GOOD	GOOD TO FAIR	GOOD TO FAIR	POOR
RESISTANCE TO MELTING (FROM HOT IRON OR LIGHT BULB)	EXCELLENT	GOOD	EXCELLENT	GOOD	POOR
DURABILITY OF STAIN RESISTANCE	EXCELLENT TO GOOD	GOOD TO FAIR	EXCELLENT	EXCELLENT	EXCELLENT
RESISTANCE TO FADING	EXCELLENT TO GOOD	GOOD	EXCELLENT TO GOOD	EXCELLENT TO GOOD	EXCELLENT
RESISTANCE TO DAMAGE FROM CHAIR CASTERS	EXCELLENT TO GOOD	EXCELLENT TO GOOD	FAIR TO POOR	FAIR TO POOR	FAIR TO POOR
BUILT-IN PERMANENT STATIC CONTROL	ALWAYS	SOMETIMES	NO	NO	NO

In this table, Invista rates the performance of five different carpet fibers:

1. Stainmaster Nylon Type 6,6 Fiber
2. Nylon Type 6 fiber
3. Polyester PET (2GT)
4. Polyester PTT (3GT)
5. Olefin Polypropylene.

This table lists two carpet attributes which are substantially the same properties as those identified by Petitioners in the Petition.

> "Appearance Retention", which is comparable to "The pile of the carpet stays tight and will stand up like new after normal vacuuming"
>
> "Resistance To Foot Traffic & Furniture Weight", which is comparable to "The carpet will stand up to years of foot traffic without matting down"

The Invista table (which significantly lists PTT **separately** from PET), rates the performance of PTT as EXCELLENT TO GOOD and conventional PET as POOR with respect to both of these properties. If, as stated at page 26 in the Conclusions to Invista's November 9 comments to the Petition, the results of the testing submitted by Petitioners "do not establish performance differences that are material to consumers," Petitioners ask:

> Why did Invista in Figure 1 include a separate column for carpets made from PTT fibers?
>
> and
>
> What caused Invista to rate PTT so highly with respect to these two important carpet attributes?

b) Petitioners' Comments Regarding Submission By Invista

The only comments submitted in opposition to the Petition were submitted by Invista S.a.r.l., one of the world's largest integrated producers of man-made fibers. Invista's carpet fiber products are mostly based on nylon, which is the highest price man-made fiber used to manufacture carpet. Significantly, Invista does not supply PTT polymer or PTT fibers for use in carpet applications. Accordingly, the availability of carpet made from PTT fibers and informed consumers who are given a tool (a new generic) to differentiate PTT fibers from lower performance PET fibers represents a competitive threat to Invista. This may explain why Invista's November 9, 2007 comments seem to be inconsistent with the information provided at its web site (Figure 1) and from all of the other comments submitted to the FTC.

Invista summarizes its arguments in Paragraphs III (a) and III (b) of its November 9 submission. Paragraph III (a) beginning on page 3 discusses Carpet Products. Paragraph III (b) beginning on page 5 discusses Apparel Products. These arguments receive further elaboration on pages 7-21 (with respect to Carpet Products) and on pages 21-25 (with respect to Apparel Products).

Petitioners will respond to Invista's arguments point by point. The Invista arguments copied from Invista's Summary Of the Argument on pages 3-5 of its Opposition are indented and set forth in red bold Italics.

> *Carpet Products*
>
> ***The Petition contends that PTT-based carpets are both more durable and softer than PET-based carpets. However, the Petition fails to establish a significant difference in these characteristics for the following reasons:***
>
> ***1. The Petition does not provide a reliable or meaningful methodology for establishing a significant difference in durability. The Petition purports to establish that, after being subject to certain wear testing, PTT-based carpets look better than PET-based carpets. The tests used by Petitioners are unreliable for a number of reasons: (a) the Petitioners compared finer, lighter weight PET fiber with thicker, heavier weight PTT fibers, thus, making a meaningful comparison impossible; (b) the Petitioners' light-weight testing is not the type of rigorous testing that reveals significant differences in fiber durability; and (c) the reported differences in durability are too modest to be relevant to consumers. In fact, Invista's own test examples illustrate that there is likely no meaningful difference between the two fiber types in durability.***

Petitioners respond to this argument as follows:

The tests summarized at pages 13-15 of the Petition and in Appendix A were performed by Mohawk. Though the Petition correctly reports at page 14 that the carpets tested by Mohawk were of identical constructions, the dpf numbers provided in Appendix A with respect to PET were incorrectly transcribed by Mohawk in preparing Appendix A. In fact, Mohawk advises that the PTT and PET fibers used for the test were of identical dpf ("denier per filament"). The actual dpf used for PET fibers was 18, the same dpf as was used for PTT fibers. Accordingly, Invista's argument is based on an incorrect assumption.

Responding to Invista's criticism of Mohawk's testing method, Mohawk advises did in fact use the heavy ball in conducting the test as advocated by Invista. Again, Invista's argument is based on an incorrect assumption.

With respect to the significance of the observed differences between the performance of PTT and PET in the Hexapod Wear Test, the observed differences between the two polymers are significant. Petitioners again refer to Figure 1 (Invista's web page) where PTT was rated "Excellent to Good" and PET was rated "Poor." Petitioners assume that Invista would regard the difference between "Excellent to Good" for PTT and "Poor" for PET to be more than a modest difference. Invista argues that both with respect to the hexapod test and the PAR test, a difference of 1.0 on the five point scale is too small for the consumer to observe. Petitioners refer to actual pictures of carpets published on the Carpet and Rug Institute web page (link set forth below). These pictures show carpets with varying degrees of wear performance. These pictures demonstrate that a 1.0 difference in performance (which was observed by Mohawk with respect to the hexapod and PAR comparison tests) would be noticeable and very important to consumers. See Figures 9-14 from the Petition.

http://www.carpet-rug.org/commercial-customers/selecting-the-right-carpet/quality-and-performance/retention-rating-scales.cfm

After criticizing Petitioners' testing methods which were based on industry standard testing methods adopted by the Carpet and Rug Institute, Invista reports that it tested 60 ounce carpet samples made from PTT and PET fibers using a proprietary Invista testing method. Petitioners cannot explain the difference between the test results obtained by Invista vs. the test results obtained by Mohawk as reported on pages 14-17 of the Petition. However, the results of Petitioners' tests showed that PTT performed comparably to nylon rather than PET across a wide range of carpet styles typically purchased by consumers[2]. Because the Invista tests were not performed using industry standard testing methods and were performed using carpet weights that consumers rarely purchase, Petitioners submit that the Invista test results are of no relevance. We again refer to the fact that in Figure 1 above, Invista describes the performance of nylon type 6 and PTT fiber as Excellent to Good while the performance of polyester fiber was described as Poor.

> *2) The Petition's presentation on softness lacks any method for testing the proposition that PTT-based carpets will be perceived as softer than PET based carpets by the general public. Rather than submitting any survey or test results as to how soft the PTT fibers actually feel in a carpet application, the Petition submits irrelevant laboratory test results regarding fiber "deflection" properties, a test of no significance to consumers in evaluating the softness of carpets. The absence of any consumer studies or surveys comparing the subjective experience of carpet softness means that the Petitioners have presented no evidence to substantiate their claim that PTT fibers result in softer carpets.*
>
> *3) The Petition fails to address how different manufacturing techniques affect softness. In particular, the Petition fails to establish that the use of PTT fibers is essential to achieve a particular level of softness and to exclude the possibility that the same level of softness can be achieved using PET fibers and different manufacturing techniques.*

Petitioners respond to both of these arguments as follows:

Petitioners based their arguments about carpet softness on the observation that carpet fibers that bend more easily are perceived to be softer. An illustration of the connection between flexibility of fibers and perceived softness is that a brush made from flexible polymer fibers is going to be perceived as softer than a brush made from stiff steel wire of equal cross section. Petitioners chose to submit stress vs. strain curves in support of its arguments rather than subjective consumer testing of perceived softness because the FTC's published requirements for approval of a new generic subclass required Petitioners to submit evidence regarding distinctive properties of importance to the general public ***"as a result of a new method of manufacture or substantially***

[2] Mohawk data indicates that most consumers purchase carpets for their homes in the 35-45 oz per square yard weight range and that only a small percentage (approximately 10%) of consumer carpets are sold in the 60+ oz weight range. The average weight is less than 40 oz. For this reason, Petitioners conducted their tests on carpet samples that are representative of what most consumers purchase for their homes.

differentiated physical characteristics, such as fiber structure," not subjective consumer tests. Petitioners chose to submit test results based on the unique chemistry and molecular and fiber structure because this is what is required by the FTC's published advice regarding those factors that are required to establish a new generic fiber subclass. See 67 FR 7104. In recognition of this requirement, generic names for fibers have historically been based on the identity of the polymer used to manufacture the fiber and the physical properties of the polymer, not the way an individual fiber is spun or manufactured. Accordingly, Petitioners arguments were based on scientific evidence as required by the FTC, not subjective consumer tests.

Invista has argued that softness can be influenced by factors in addition to the physical characteristics of a polymer such as how the tips of fibers are manufactured or finished. It is true that fiber manufacturing methods, as well as the inherent physical properties of the fiber, can influence softness. Carpets made from Invista's Tactesse nylon fibers are perceived as soft because they are made with lower denier fibers which of course bend more easily to the touch than higher denier fibers. The use of smaller denier fibers can make any type of carpet feel softer. However, fiber manufacturing methods are not the kind of fiber characteristics that have been used by the FTC to approve the use of new fiber generics or generic subclasses.

The flexibility properties of PTT described at pages 19-20 of the Petition cause fibers of equal deniers made from PTT to appear softer than fibers made from nylon or PET.

Apparel Products

1) The Petition fails to present the results of any reliable testing methodology demonstrating that PTT fibers "recover" from stretching better than PET fibers. The Petition describes a single comparison in which particular PTT and PET fabrics were subjected to a high stretching force and then retracted. The Petition argues that, while the PET- based fabric stretched more at a given force level, it showed a slightly greater permanent level of deformity from its original shape than the PTT – based fabric. However, Petitioners' test failed to establish: (1) that the amount of force used in the test was relevant to the amount of force usually applied to garments in real – life situations; (2) that the slight differences in retractability between the two samples was meaningful to consumers; or (3) that PTT fabrics result in less distortion than PET fabrics for identical stretch distances.

Petitioners submitted stretch and recovery data comparing PET and PTT fibers in Figure 8 on page 13 of the Petition. These test results were reported in greater detail in the paper listed as Reference 5 to the Petition, a copy of which is attached to Petitioners' response. In this paper, identical fibers made from different polymers were tested under identical conditions. The test results, as reported in Figure 8 of the Petition, report the significantly better stretch and recovery properties of PTT fibers compared to PET fibers. As one might expect, the superior stretch and recovery properties of PTT fibers carried over into fabrics made from PTT. See Figure 17 set forth at page 22 of the Petition.

Invista criticizes Petitioners' test methods for comparing fabrics. However, as required by the FTC (see 67 FR 7104), Petitioners' arguments are based on the qualities of the fiber. Importantly, Invista does not question the test data in Figure 8 which establishes

the fact that PTT fibers have significantly greater stretch and recovery than comparable fibers made from PET. The data submitted by Petitioners with respect to knitted and woven fabrics merely confirms the results that one would expect from the properties of the fiber.

> *2) The Petition fails to demonstrate that PTT fabrics are softer than fabrics made with PET. As in the case of carpet fibers, the Petition fails to present any reliable methodology for testing the experience of softness in garments made with PTT fibers that is relevant to consumers.*
>
> *3) The Petition fails to address how different manufacturing techniques affect softness. Again, the Petition fails to establish that the use of PTT fibers is essential to achieve a particular level of softness and to exclude the possibility that the same level of softness can be achieved using PET fibers and different manufacturing techniques.*

Arguments 2 and 3 submitted by Invista regarding the softness of fabrics made from PTT make the same points raised with respect to carpet softness. Petitioners restate their observations regarding Invista's arguments as set forth above with respect to carpets. In addition, Petitioners refer to the supportive comments from the Italian fabric manufacturer set forth above. These comments emphasize both the softness and stretch and recovery of fabrics made from PTT fibers.

c) <u>The Generic Names Proposed By Petitioners</u>

Invista has raised objection to two of the generic names proposed by Petititioners, resisoft and durares, because of their alleged similarity to Invista brand names for carpet cleaning products (ResisTech) and soil resistance treatments (DuraTech). Petitioners do not believe there is any confusing similarity between the proposed generic names in question and these trademarks. However, Petitioners note that Invista has not raised any objection to the first candidate proposed by Petitioners, triexta. Accordingly, Petitioners propose that should the FTC find that designation of a new generic subclass for PTT fibers is appropriate, **triexta** should be chosen as the name of the new generic.

Questions regarding this Response may be addressed to:

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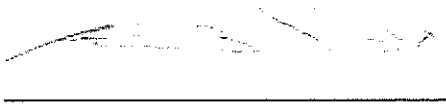
PTT Poly Canada, L.P.

By 

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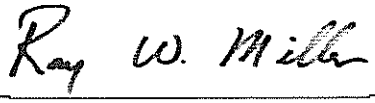
By 

JOURNAL OF POLYMER SCIENCE: Polymer Physics Edition VOL. 14, 263–274 (1976)

The Mechanical Properties and Structure of Poly(*m*-methylene Terephthalate) Fibers

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Synopsis

A study has been carried out of the differences in mechanical properties of oriented fibers of poly(ethylene terephthalate) (2GT), poly(trimethylene terephthalate) (3GT), and poly(tetramethylene terephthalate) (4GT). The properties studied include the tensile stress–strain behavior, the recovery from strain, shrinkage at 100°C and the glass-transition temperatures. The stress–strain curves of the three materials differ markedly. 2GT shows a monotonic increase in stress with increasing strain up to failure, which occurs at ~20% strain, and the oriented fibers possess a comparatively high initial modulus. 3GT shows a much lower initial modulus and there is an inflection in the stress–strain curve at about 5% strain. The stress–strain curve of 4GT shows a number of distinct features. Although the initial modulus of 4GT is similar to that of 3GT, the stress–strain curve shows a pronounced plateau in the region between 4% and 12% strain. At higher strains the stresses rise rapidly before failure. These features of the stress–strain curves in the three polymers can be related to previous studies where the x-ray diffraction spectrum and the Raman spectrum have been examined for fibers under stress. The ranking of both the recovery and shrinkage behavior of these materials is in the order 3GT > 4GT > 2GT. These results can also be understood in terms of the results of the previous structural studies, and it is concluded that the molecular conformations in both the crystalline and noncrystalline regions play a key role in determining the mechanical behavior.

INTRODUCTION

Although many aromatic polyesters can form oriented fibers and films with comparatively good mechanical properties in terms of stiffness and strength, only in the case of poly(ethylene terephthalate) have extensive studies been undertaken of the relationship of mechanical properties to structure.[1–3] The present paper considers the mechanical behavior of three related polyesters, poly(ethylene terephthalate) (2GT), poly(trimethylene terephthalate) (3GT), and poly(tetramethylene terephthalate) (4GT). It also attempts to gain an understanding of this behavior in terms of our existing knowledge concerning the structural changes which occur on deformation. In this it has been possible to draw on information gained in recent structural studies which have been reported elsewhere.[4,5]

EXPERIMENTAL

Preparation of Samples

Special samples of each polyester were prepared free from delustrant, each at two levels of molecular weight as determined by the relative viscosity of a

1% solution in *o*-chlorophenol at 25°C. The polymers were spun on a laboratory melt-spinning equipment to produce a spun yarn with five filaments, except for the high molecular weight 3GT sample which was spun on a rod-spinning equipment to give a yarn with three filaments. Each of the spun yarns was drawn on a Meccano draw frame, over a heated roller (the pin) and a heated plate, to three draw ratios. The spinning and drawing conditions, together with some of the physical properties to be discussed, are given in Table I.

Tensile Measurements

Load-extension curves were determined on single filaments mounted on cards using an Instron tensile testing machine. For each material, twenty 5-cm samples were tested at a crosshead extension rate of 5 cm/min and the load-extension curves averaged to give a single curve. The load is quoted as nominal stress, i.e., load divided by initial cross-sectional area which was determined separately for each filament using a vibrascope. The moduli quoted from these data are 2% secant moduli, calculated from the nominal stress at 2% strain.

Recovery Measurements

The recovery test is shown schematically in Figure 1, where the terms used are also defined. The filament is initially extended in an Instron tensile testing machine to the required strain (at a crosshead speed of 2 cm/min), and then held at constant strain for 2 min, after which the crosshead is returned to its original position. After a further 5 min, the filament is then re-extended. Below a certain strain the filament re-extends immediately after this 5 min waiting period, but at higher strains there is some slack in the filament which we term "permanent set." The "immediate recovery" is defined as the strain recovered after the first 2 min stress relaxation, and the "total recovery" as the strain recovered after the full cycle (2 min at constant strain, followed by return of the crosshead, followed by 5 min waiting period). It has also been found useful to compare the recovery behavior of different fibers by comparing the applied strains at which the recovery is 95%. This quantity will be termed the "specific recoverability" and may be applied to either the immediate or total recovery.

Shrinkage Measurements

The shrinkages of the fibers were determined by measuring the change in length of 100 meters of each fiber, after immersion in boiling water for 15 min, care being taken to allow free shrinkage.

Dynamic Mechanical Measurements

Dynamic mechanical measurements were carried out on the drawn fibers using the TFA (Transfer Function Analyser) testing equipment, which has been described in detail in a previous publication.[6] The measurements were

TABLE I
Spinning and Drawing Conditions and Some Physical Properties of the Fibers

Polymer	Wind-up speed, ft/min	Pin temp., °C	Plate temp., °C	I.V.	Spun Δn	Draw ratio	Decitex (filament mean)[a]	Tenacity, GNm^{-2}	Breaking extension, %	2% secant modulus, GNm^{-2}	Shrinkage (boiling water), %	Birefringence
2GT	3000	100	170	0.50	0.0042	3.50	3.5	0.43	44	8.1	3.1	0.156
						3.75	3.4	0.49	34	10.3	3.4	0.164
						4.00	3.1	0.53	21	10.9	3.5	0.177
				0.72	0.0075	3.00	4.1	0.45	39	7.7	4.6	0.146
						3.33	3.7	0.51	25	8.9	5.4	0.159
						3.75	3.3	0.69	22	9.2	5.6	0.172
3GT	3000	70	90	0.59	0.0048	3.20	4.1	0.24	49	2.6	13.6	0.069
						3.50	3.6	0.28	47	2.6	T4.1	0.073
						3.75	3.7	0.30	40	2.4	—	0.73
				0.65	0.0052	3.00	4.4	0.30	69	2.7	14.3	0.070
						3.75	3.6	0.35	38	2.4	—	0.073
						4.00	3.3	0.37	32	2.7	16.4	0.073
4GT	4200	90	160	0.54	0.064	1.50	4.6	0.24	107	2.4	8.0	0.146
						2.00	4.6	0.32	54	2.2	7.2	0.157
						2.60	3.6	0.49	20	2.6	6.0	0.158
				0.72	0.065	1.50	5.7	0.24	95	2.6	8.0	0.148
						2.00	4.6	0.32	54	2.0	8.1	0.154
						2.60	3.6	0.50	23	2.3	6.5	0.161

[a] For a density of 1 g cm^{-3}, 1 decitex is equivalent to a cross-sectional area of 10^{-10} m^2.

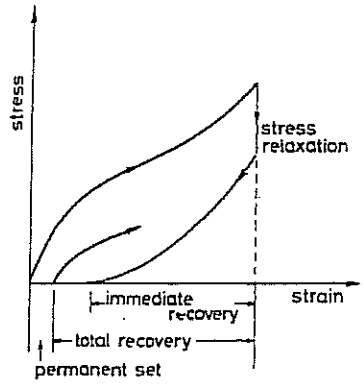


Fig. 1. The recovery cycle and definition of terms.

undertaken on a carefully aligned bundle of 20–30 filaments, of length 10 cm. A fixed frequency of 1 Hz was selected, and the temperature range was from ambient to 170°C. These measurements provided a comparative measure of the glass-transition temperature T_g for the oriented fibers, defined as the temperature corresponding to the maximum in the dynamic loss (tan δ) at the frequency of 1 Hz.

RESULTS

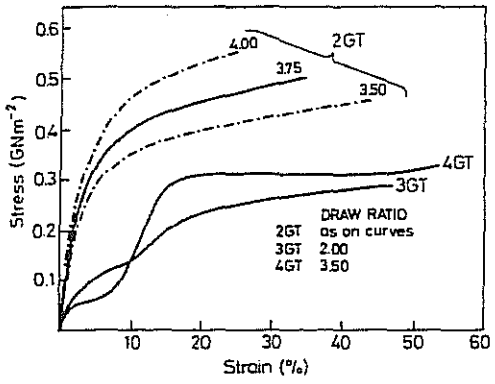
The room temperature load-extension curves are shown in Figure 2. They are grouped according to molecular weight, although this appears to have very little effect on their shape. To avoid confusion and aid comparison these curves are for the middle draw ratio of each species since it is only the relative shape of the load-extension curves that is important. The effect of changes in draw ratio are shown in Figure 2a for 2GT; they affect the absolute level of properties, but do not change the shape of the curve. This is also true for 3GT and 4GT. The property level changes (i.e., tenacity and breaking extension) are shown in Table I.

Figure 2c shows the relaxed stress–strain curves of 3GT and 4GT compared with the constant strain rate curves. The relaxed stress–strain curves were obtained on the Instron by increasing the strain in steps of 1%, and measuring the stress at each strain level after stress relaxation for 2 min.

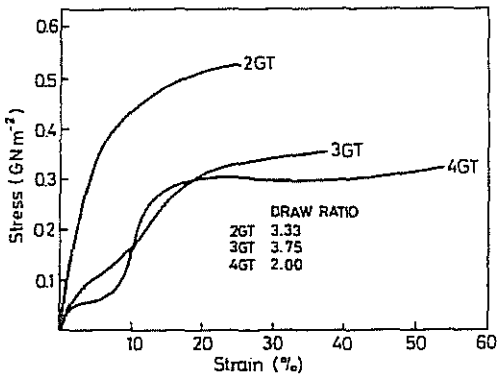
The total recoveries, immediate recoveries, and permanent sets are plotted in Figure 3 for all molecular weights and draw ratios, since the small changes due to these parameters do not produce any appreciable scatter in the results.

The 2% secant moduli for the curves of Figure 2b, the high molecular weight samples, are plotted in Figure 4 versus the number of methylene groups. The glass-transition temperature T_g for the fibers is plotted in a similar manner in Figure 5. (The spread shown for each point represents the range of values obtained in three separate determinations.)

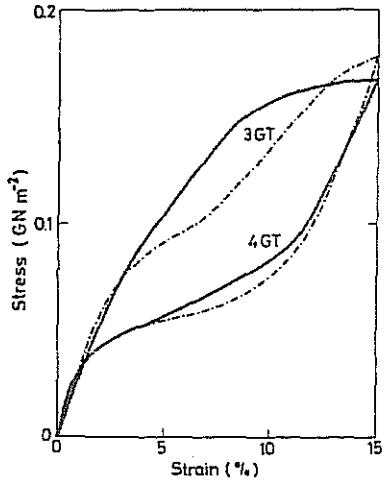
The strain at which the total recovery curve leaves the abscissa in Figure 3a represents the maximum strain before permanent set occurs. It can be seen that this point is somewhat indeterminate, due to the asymptotic nature of the relationship, hence the usefulness of comparing the strain for 95% total



(a)



(b)



(c)

Fig. 2. Stress–strain curves of the fibers, (a) low molecular weight, (b) high molecular weight, (c) stress-relaxed curves of 3GT and 4GT compared with the constant strain-rate curves. Solid curve, relaxed; dashed curve, constant strain rate.

recovery, which we have termed the specific recoverability. This is plotted as a function of draw ratio in Figure 6 together with the boiling water shrinkages. The results for samples of different molecular weight have been separated to show that the differences between them is not significant.

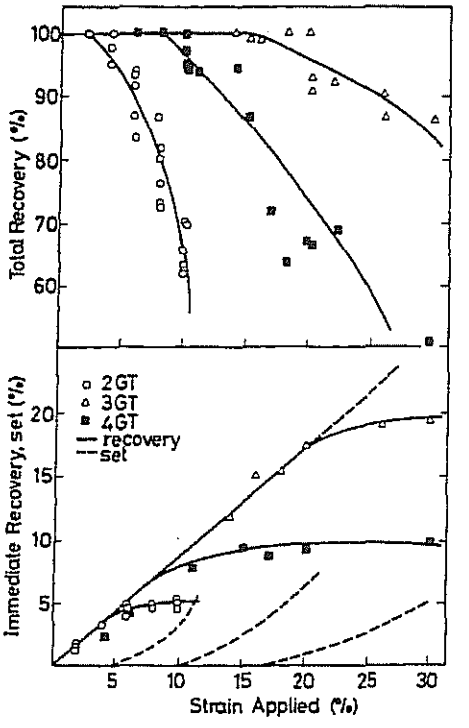


Fig. 3. Total recoveries, immediate recoveries, and permanent sets of the fibers vs. applied strain.

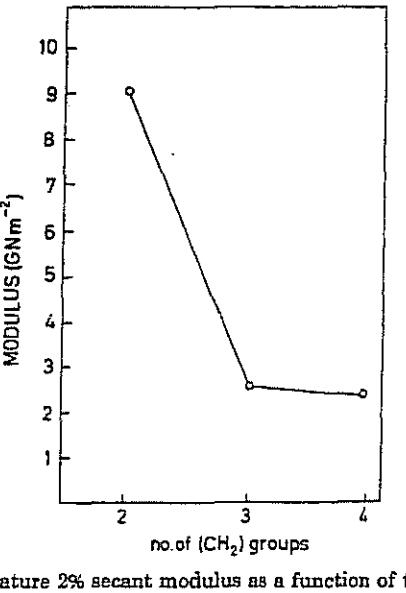


Fig. 4. Mean room temperature 2% secant modulus as a function of the number of methylene groups in the monomer unit.

The effect of heat treatment on the fibers was investigated by placing them in a relaxed condition in a preheated air oven for 10 min. The shrinkage during annealing was about 25%. Figure 7 shows the effect on the stress–strain curves and on the recovery. The effect of heat treatment on recovery is summarized by Table II, which shows the strain for 95% total recovery for each fiber before and after the annealing treatment.

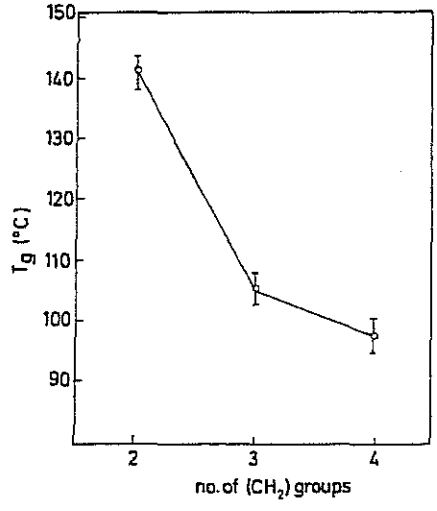


Fig. 5. Mean glass-transition temperatures as a function of the number of methylene groups in the monomer unit.

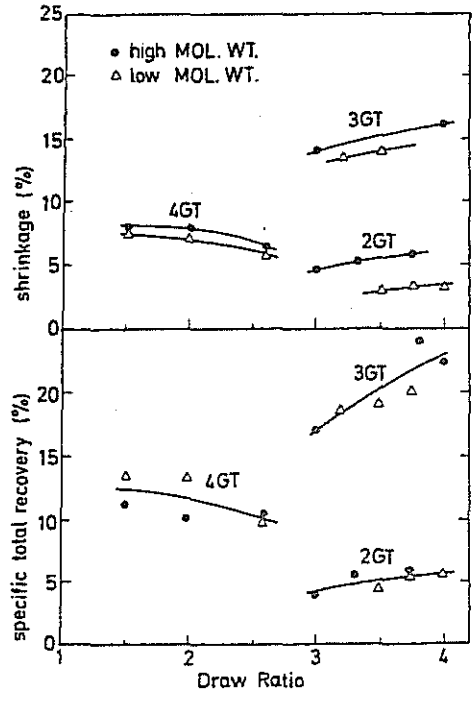


Fig. 6. Shrinkages and specific total recoveries as a function of draw ratio.

TABLE II
Effect of Annealing on 2% Secant Modulus and Specific Total Recoverability

GT	Property	Annealed	Unannealed
2	Modulus, gNm^{-2}	5.23	9.15
	Specific recoverability	2.1%	4%
3	Modulus, gNm^{-2}	3.88	2.58
	Specific recoverability	2.1%	22%
4	Modulus, gNm^{-2}	2.6	2.4
	Specific recoverability	4.9%	10.6%

All the results shown in Figure 7 and Table II are for a single molecular weight and draw ratio of each fiber type. This is because these mechanical properties are insensitive to these parameters, as has already been emphasized.

DISCUSSION

The major problem in comparing fibers by relating fiber properties to structure is that of establishing a reference level. It is difficult to know *a priori* whether the properties in question are due to fundamental differences in molecular structure or whether they are due to the methods used for preparing the fibers. The best that can be done is to prepare the fibers under as comparable conditions as possible.

Draw ratio is clearly a variable which could override molecular structure. With this in mind, a range of draw ratios was obtained for each molecular weight. The range was rather limited, and in the case of 3GT and 4GT the

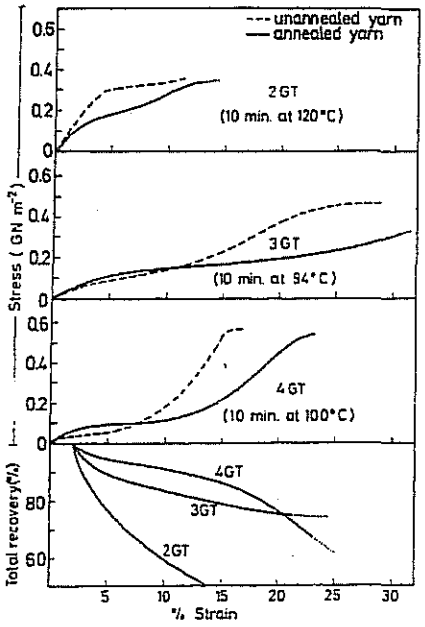


Fig. 7. The effect of annealing on the stress–strain curves and total recoveries of the fibers.

highest draw ratio was the maximum which could be obtained without altering the drawing conditions. The lowest draw ratios were those below which the yarn began to slough on the bobbins. The sensitivity of gross behavior to small changes in draw ratio was found to be very low, over this range, and so, for further work, it was assumed that draw ratio was not a critical parameter. Molecular weight is another important variable, and the molecular weights were matched as closely as possible. As with draw ratio, the use of two levels of molecular weight for each species showed that this was not a critical variable in the molecular weight range used.

The chief point of difference between the three fiber types is the shape of the stress–strain curves, as shown in Figure 2. 3GT and 4GT have a primary yield at about 5% strain. This shows as a pronounced knee or plateau region and is most evident in 4GT. 2GT, on the other hand, does not display this characteristic. The plateau is followed by a strain hardening region, the onset of which, in 3GT, is at about 12–15% strain, and in 4GT is about 8% strain. A second yield point is ultimately reached before failure. The plateau region in 3GT and 4GT appears to be closely related to recovery, as shown by Figure 3. For unannealed fibers, at least, the total recovery does not start to decrease until the strain has reached the strain hardening region at the end of the plateau. The immediate recovery also falls off near this point.

The second major difference between the fibers is that the modulus of 2GT is much greater than either 3GT or 4GT, with 4GT being slightly less than 3GT. The final very clear difference between these three fibers comes from the comparison of shrinkage and recovery behavior shown in Figure 6. It is extremely interesting to note that the ranking is the same for both shrinkage and recovery, with the order 3GT > 4GT > 2GT.

The x-ray diffraction studies reported in the previous publication[4] show that there is a major difference between the molecular conformations in the crystalline unit cells of these three polymers. In 2GT the c-axis dimension corresponds to a molecular conformation which is very nearly planar with the chains almost fully extended. In 3GT, on the other hand, the fiber identity period is only 76% of the repeat distance for a fully extended chain and it appears that the molecular conformation is helical with successive monomer units lying at approximately 60° to one another about the helix axis. Although 4GT shows a unit cell dimension in the c-axis direction which is markedly longer than in 3GT, the value corresponds only to 86% of the fully extended chain repeat distance.

The comparatively low modulus of 3GT and 4GT can therefore be associated with the fact that the molecular conformation never corresponds to the fully extended form so that deformation always involves bond angle rotations and bond bending rather than bond bending and stretching. It is interesting that in 3GT the x-ray measurements of the strained fibers show that the deformation of the crystalline regions is approximately identical with the overall deformation, i.e., the lattice deforms like a coiled spring. The low overall modulus in this case corresponds exactly to the low crystal modulus. In 2GT the measured macroscopic modulus is much less than the crystal modulus (as shown by Dulmage and Contois[7]). Nevertheless there is still a proportion of molecules taking the stress which are in the fully extended form. These

would correspond to the tie molecules which Peterlin has proposed for crystalline fibers of polyethylene.[8]

The dynamic mechanical results (Figure 5) show that the glass-transition temperature T_g is also very considerably lower in 3GT and 4GT than in 2GT. This can also be attributed to the increased flexibility of the two former polymers due to the more crumpled conformation of the glycol residue.

The x-ray diffraction studies[4,5] also included measurements of the deformation of the crystalline regions of 3GT and 4GT when the oriented fibers or tapes were extended. It was found that in both cases there were comparatively large reversible lattice strains. In the case of 3GT, the lattice strains increased monotonically with increasing macroscopic strain and at low strains these were approximately identical. Thus the initially linear part of the stress–strain curve in 3GT corresponds to an elastic uncoiling of the molecules, which the structural studies have shown to take up helical conformations, as discussed above. It is therefore not surprising that the recovery of 3GT from strain is very good, particularly at low strains. It is also not surprising that the onset of nonrecoverable strain corresponds approximately to the end of the plateau region where there is a distinct inflection in the stress–strain curve. In molecular terms it can be inferred that this occurs when the macroscopic strain causes irreversible movements of the molecular chains. At this point the deformation becomes inhomogeneous at a molecular level, so that the deformations in the crystalline and noncrystalline regions now begin to differ appreciably.

In 4GT, the x-ray diffraction studies on strained fibers reveal a somewhat different pattern of behavior at a molecular level. In this case there is no detectable change in the x-ray diffraction pattern at low macroscopic strains. At a macroscopic strain of about 4%, reflections corresponding to a unit cell in which the molecular chain is fully extended start to appear in the diffraction pattern. As the macroscopic strain is increased from 4% to about 12% these new reflections grow in intensity, and those corresponding to the zero strain unit cell diminish, so that there is a complete transformation of the material in the crystalline regions from one crystal form to the other. In 4GT the knee in the stress–strain curve therefore corresponds to the onset of this crystal transformation. It can be considered to correspond to a yield point for this process, and the plateau region of the stress–strain curve corresponds to increasing strain in the crystalline regions as the crystalline material transforms at constant stress, very similar to classical plastic flow. When this process is exhausted, further deformation can only proceed by processes which require greater stress for their activation, and the stress–strain curve rises again. This deformation of the crystalline regions has been shown by x-ray and Raman spectroscopy measurements to be completely reversible.[5] Recovery in 4GT is therefore also associated to a major degree with the elastic recovery of the crystalline regions. The mechanical recovery in quantitative terms (see Figs. 3 and 6) is not as good as in 3GT, and this can be attributed to the fact that the crystal deformation process is exhausted at about 10% macroscopic strain, whereas the elastic distortion of the crystalline regions in 3GT continues to the highest strains and is reduced in magnitude only as the whole structure is disrupted and the distribution of stress becomes very inhomogeneous at a molecular level, as already discussed.

Finally there is the comparison of shrinkage and recovery behavior shown in Figure 6 which indicates very clearly that these two properties have equivalent ranking and behavior over the range of draw ratios. This is a very important observation, the significance of which is not yet fully understood, but from our discussion above it can be inferred that a common factor such as the geometrical shape of the molecular chain is involved. This common factor is involved in the molecular mechanisms responsible for both recovery from extension and in reduction in length in shrinkage. This is not surprising if both recovery and shrinkage involve the contraction of an extended network. The results imply that 3GT has a greater number of effective random links between network junction points than 4GT, which in turn has a greater number than 2GT. This line of argument points back to the basic molecular flexibility which in terms of the molecular conformations in the crystalline regions ranks these three polymers in the same order. Thus, although shrinkage is a process involving only the amorphous regions and their disorientation, the general link is that the conformational situation is at a molecular level, and therefore affects both the crystalline and the noncrystalline material.

The main effect of annealing in all these fibers is to cause large scale disorientation of the amorphous network.[9,10] The network may be thought of as an entropic rubber which possesses an equilibrium extension for any given temperature. When the fiber is annealed the increase in temperature causes a shrinkage because the network attains a new equilibrium extension. As the fiber is cooled to room temperature this new configuration is "frozen". The fiber is now extended. Because the network is more crumpled than in the initial fiber, the extension in the plateau region is greater. In addition, when the stress is removed the network will revert back not to its annealed configuration, but to the equilibrium state at room temperature. Thus, the recovery is much reduced. This argument may equally well apply to both 3GT and 4GT, and since the recovery of the crystal lattice now plays little part in the recovery of the annealed fiber it is not surprising that after annealing the recoverabilities of the two species are very similar.

After annealing the fibers, another important observation is that the modulus of 2GT drops very appreciably (from 9.3 to 6.2 GN/m^2) and that of 3GT and 4GT actually increases slightly (from 2.7 to 3.8 GN/m^2 for 3-GT, and from 2.3 to 2.95 GN/m^2 for 4GT). It is easy to explain the decrease in the 2GT modulus. The relaxed heat treatment causes the amorphous regions to relax and since these regions control the modulus, the modulus will be correspondingly reduced. In 3GT and 4GT, on the other hand, it can be implied that the molecules in the noncrystalline regions are in crumpled conformations with a correspondingly low modulus. In this case the increased crystallinity on annealing leads to a small increase in modulus. The corresponding reduction in recovery of 3GT and 4GT on annealing is also consistent with the removal of the flexible crumpled conformations in the amorphous regions. It appears that this effect is greater than the increase in recovery which might be expected due to a greater proportion of crystalline material with high elastic recovery.

In 2GT, the much earlier studies of Dulmage and Contois[7] showed that the strain in the crystalline regions was a factor of about ten less than the macroscopic strain for macroscopic strains up to 1.8%. The stress–strain behavior

must therefore be associated mainly with deformation of the amorphous regions. As we have mentioned the high modulus is consistent with the stress being taken by a few extended tie molecules. In this case it is therefore reasonable to find that there is not a knee in the stress–strain curve, as there is no dramatic change in the nature of the deformation with strain.

It should be mentioned that a knee can be produced, followed by a plateau region, if the 2GT fibers are annealed.[10] The plateau region produced by annealing in 2GT is, however, not similar to that present in unannealed 3GT and 4GT in that it does not represent a region in the stress–strain curve where there is good recovery from strain. This suggests that the plateau in this case has a quite different origin at a structural level, and possible explanations have been proposed by Wilson.[10]

CONCLUSIONS

(*1*) There are very distinct differences between the mechanical behavior of oriented fibers of 2GT, 3GT, and 4GT which are irrespective of the smaller differences produced in each species by changes in molecular weight or process draw ratio.

(*2*) The different nature of the stress–strain curves for these three materials, including their initial moduli, can be fairly well understood in terms of the previous structural studies.[4,5] In particular, there is a substantial contribution to the overall deformation in 3GT and 4GT which arises from deformation of the crystalline regions. This feature also provides a satisfactory explanation of the different recovery behavior of 2GT, 3GT, and 4GT.

(*3*) The correlation between the ranking of these three materials with regard to recovery from strain and shrinkage at 100°C suggests that the molecular conformational state in both the crystalline and noncrystalline regions is the underlying factor in determining the physical properties of these polymers.

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Received August 11, 1975